LEVEL III

(12)

Rockwell International

(14) MRDC41081.2RD

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CONTRACTOR: Rockwell International/MRDC

CONTRACT NO. (15) N00173-80-C-0485 ✓ WARPA Order-4036

CONTRACT AMOUNT: $350,000

EFFECTIVE DATE OF CONTRACT: 09/18/80

(11) 1981

EXPIRATION DATE OF CONTRACT: 11/17/81

PRINCIPAL INVESTIGATOR: (10) P. D. Dapkus

TELEPHONE NO.: 805/498-4545

SHORT TITLE OF WORK: (6) Integrated Optical Transmitter and Receiver.

REPORTING PERIOD: 01/01/81 through 03/31/81

(9) Status Rept. no. 2, 1 Jan-31 Mar 81,

A. DESCRIPTION OF PROGRESS:

Integrated/Electronic Driver Development

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Chip layout of electronic driver circuits utilizing TELD's, FET's, and resistors were completed. Six driver configurations were designed into a unit cell to anticipate diode laser threshold prebias currents of 40 to 150 mA and modulation currents $\sim 0.2\ I_t$ to $3\ I_t$ depending on the driver and laser threshold combination. The electronic driver was designed to be compatible with a TJS, diffused-stripe, or other laser structure grown in an etched groove in the S. I. GaAs substrate for planar electronic driver processing.

Generalized processing steps for the fabrication of planar integrated transmitter structures were formulated. The feasibility of key planar processing steps were demonstrated. Growth of MO-CVD GaAs into an etched groove in S. I. GaAs with subsequent etch processing to yield a planar surface was demonstrated. This groove growth verifies the capability of achieving planar GaAlAs/GaAs/GaAlAs laser structures in S. I. GaAs. Selective implantation rather than epitaxial techniques used to fabricate

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electronic devices offer the advantages of (1) higher performance (eliminating the deleterious effects of grown interface), (2) greater control and reproducibility, and (3) compatibility with planar processing techniques. Selectively implanted FET's and resistors using Se and Si are well established technologies at Rockwell via the GaAs digital IC and the microwave FET programs. However, very little work has been performed up to now on implanted Gunn/TELD devices. Sulfur implanted/diffused Gunn devices with higher current drop ratios at lower nt products than epitaxial counterparts were reported. Sulfur as an n-type implant diffuses rather easily, and a combination implant/diffusion was used in that work to achieve the necessary depths to t $\sim$ 1 μm although the doping profile was very broad.

In our work, we have used doubly-ionized Si at 390 keV to achieve deep implants to depths of $\sim$ 0.8 μm. Silicon has the advantages of being effectively immobile at the maximum laser growth/processing and implant anneal/activation temperature anticipated at $\sim$ 850°C. Flat profiles were achieved by using a triple-implant schedule including the one S^{++} and two implants using S^{+}. Reproducible deep-implant profiles were achieved in a total of 12 wafers, 6 each from a Rockwell in-house grown LEC (Liquid Encapsulated Czochlralski) and 6 from a commercial vendor, Crystal Specialties. Implant depths to $\sim$ 0.8 μm at two carrier concentration levels n $\sim 3 \times 10^{16}/cm^3$ and n $\sim 7 \times 10^{16}/cm^3$ were investigated. Mesa Gunn devices fabricated from these wafers yielded current drop ratios in the range 30 to 40%. These results are already compatible with the integrated transmitter design requirements. However, selective implantation using suitable masks needs to be developed for planar TELD development. Thick photoresist, metal/nitride, and SnO_2 (a transparent electrode material) are currently being investigated.

The integrated transmitter mask set design was completed. A nine-level mask set compatible with the formulated processing/fabrication schedule and the chip layout was designed and submitted to Electromask, Inc., for mask generation. Extra mask sets for fabricating the laser portion await decision on the final laser structure.

Laser Development

During this period, some improvements of the TJS lasers were obtained by using a spin-on Zn-doped SiO_2 film (from Emulsitone) as a diffusion source. A rotation speed of 3,000 rpm produced on the wafer an $\sim$ 0.3 μm film. After it was baked at 120°C for 15 minutes, diffusion was carried out at 850°C in a flowing argon atmosphere for $\sim$ two hours. For a 200 μm cavity length device, the threshold current was reduced to $\sim$ 90 mA. Other undesirable aspects of the laser remained unimproved.

Because of disappointing results obtained in the TJS structure, our diffusion efforts were partially directed toward the diffused stripe laser structure. The grown DH structure was similar to that used in the TJS laser fabrication except that the doping of the active layer was changed to p-type. Four μm stripe widths were etched in the deposited Si_3N_4 mask. Diffusion was made at 650°C for 15 minutes and 850°C drive-in for one to two hours. The above diffusion schedule brought the diffusion front to the active region with a well controlled width of $\sim$ 4 μm. Thresholds as low as 40 mA were observed. The typical room temperature cw threshold of a 230 μm length diode was 60 mA. Good linearity and kink-free light/current characteristics were obtained up to at least three times I_{th}. External differential quantum efficiency was 28% per facet. Power level was 3 mW at 70 mA. Single longitudinal and transverse modes were observed in a wide range of current levels. Good lateral current confinement was partly due to the minimization of leakage to the top GaAlAs layer by the presence of the isolating p active layer.

Although we have demonstrated the high performance of the above diffused stripe lasers on the n-type substrate, it requires certain modification before it can be incorporated in the integrated transmitter fabrication. We will access this feasibility in the next quarter.

B. CHANGE IN KEY PERSONNEL:

No change.

C. SUMMARY OF SUBSTANTIVE INFORMATION DERIVED FROM SPECIAL EVENTS:

Program Reviews were held for Drs. Henry Taylor and Vinton Cerf. From these reviews, it was decided to begin in the next fiscal year to address final systems aspects of chip design and integration.

D. PROBLEMS ENCOUNTERED AND/OR ANTICIPATED:

Final Diode Laser Configuration

(1) Choice of a diffused-stripe structure over a TJS laser due to prohibitively high threshold currents for the latter. Low $I_t \sim 40$ to 50 mA demonstrated for ~ 200 to 300 μm cavity for former.

(2) Laser electrical contact pick-up for a diffused-stripe structure.

Electronic Driver Development

Key device development in the electronic driver portion is the selectively-implanted TELD device. Process/fabrication compatible implant-mask for S^{++} 390 keV will be an important development issue. SnO_2 appears as an attractive mask material due to its relatively high density, transparency, and selective-etch capability. However, its deposition characteristics include Sn globule formation which must be controlled. Photoresist is difficult to work with in thick layers but requires investigation. Metal/oxide combinations are also mask alternatives which will be considered.

E. ACTION REQUIRED BY THE GOVERNMENT:

No action required by the Government.

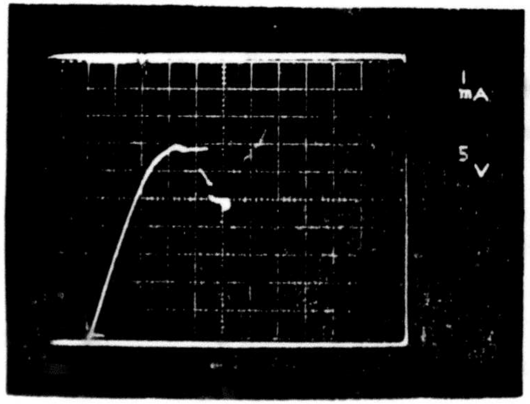
F. FISCAL STATUS:

(1)	Amount currently provided on contract:	\$350,000
(2)	Expenditures and commitments to date:	127,700
(3)	Funds required to complete work:	222,300

GaAs IMPLANTED GUNN DEVICES

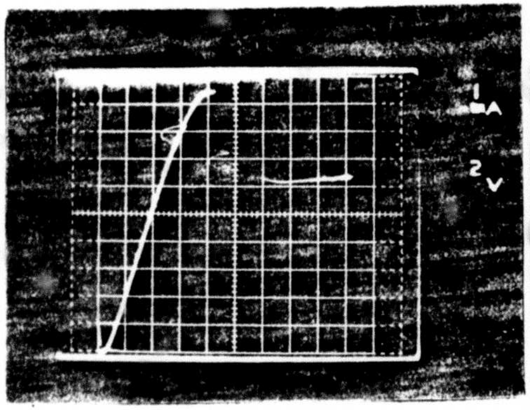
TRIPLE Si IMPLANT: FLAT PROFILE

Si^{++} (390 KeV) DEEP IMPLANT $t \cong 0.8\ \mu m$



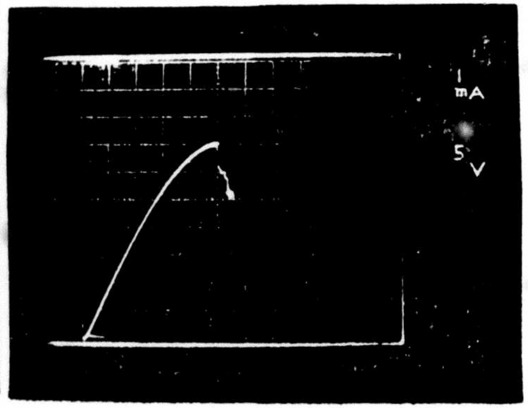
$n \cong 4.5 \times 10^{16}/cm^3$

Crystal Specialties



$n \cong 6.5 \times 10^{16}/cm^3$

Rockwell LEC



$n \cong 7.0 \times 10^{16}/cm^3$

Crystal Specialties

Rockwell International

Defense Electronics Operations
Microelectronics Research
and Development Center
1049 Camino Dos Rios
P.O. Box 1085
Thousand Oaks, California 91360

Rockwell International

Director, Advanced Research Projects Agency
1400 Wilson Boulevard
Arlington, VA 22209

Att: Program Management

Re: R & D Status Report No. 2
For period 01/01/81 thru 03/31/81
Document No. MRDC41081.2RD

In accordance with the requirements stated for Contract No. N00173-80-C-0485, ARPA Order No. 4036, enclosed herewith is R & D Status Report No. 2.

ROCKWELL INTERNATIONAL
Microelectronics Research
and Development Center

P. D. Dapkus

P. D. Dapkus

PDD:cl
Encs.
xc: Naval Research Laboratory
4555 Overlook Ave., S. W.
Washington, D. C. 20375
Att: Dr. Joseph F. Weller, Code 6570
Contract No. N00173-80-C-0485

Director, Naval Research Laboratory
Att: Code 2627
Washington, D. C. 20375

AFPRO--Rockwell International
3375 Miraloma Ave.
Anaheim, CA 92803

Defense Technical Information Center
Bldg. 5, Cameron Station
Alexandria, VA 22314

Office of Naval Research Branch
1030 E. Green St.
Pasadena, CA 91106